Introduction

With its coming transition to digital operation, the wireless cable industry will take a major step toward fulfilling its promise to be a competitive alternative to other delivery media of entertainment and information to the public. If it is to be fully competitive, however, it must have access to all the opportunities and technologies available to those other media that its resources permit. In particular, it must have a means independently to provide two-way connectivity to its subscribers without having to rely on different, potentially competing, media or carriers, and it must have the ability to reuse its spectrum as necessary to achieve the greatest efficiency that technology and capital investment will permit.

To support two-way operation and frequency reuse by wireless cable operators, appropriate FCC Rules are necessary that recognize the wide variety of situations existent among wireless cable systems, that provide for maximum flexibility in system designs and choices of technology so as to optimize use of the spectrum over time and technological development, and that assure protection from harmful interference for neighboring systems. It is the purpose of this document to show how these potentially conflicting goals can be achieved in a way that balances the interests of the many industry players while maximizing opportunities for all.

In order to match the Rules to be proposed with the requirements of the industry, it is necessary first to examine the types of operations to be supported. This examination includes the nature of the systems into which two-way operations will be introduced and the forms that can be taken by two-way systems. Since digital operation by itself provides opportunities for system configurations that were not possible with analog facilities, these, too, must be taken into consideration in devising two-way Rules. Appropriate models representative of most situations that will be faced must be contrived in order to permit sufficiently complete analysis so that the resulting conclusions can be depended upon.

Since the technology that will be used will certainly develop over time and likely will include a variety of modulation schemes, a method for handling different modulation techniques, different modulation densities, different bandwidths, and similar technical differences should be built into the Rules that are adopted. Mechanisms for treating the many possibilities that arise from various combinations of these characteristics are included in the discussion herein.

Among the many factors that must be considered in an analysis of two-way operation are system topologies, both upstream and downstream operations, transmitter power levels and spectral masks, co-channel interference, adjacent channel interference, and the methods to be applied in licensing and regulating two-way activities. Of equal importance is the current regulatory environment into which the new form of operation will be introduced. For the easiest implementation of the new technology, the existing Rules should be maintained and built upon to the extent possible. While the specific regulatory actions required are beyond the scope of this document, the technical methods and analytical tools needed as underpinnings for regulation are developed.

Of paramount importance in evolving the basis for such a far-reaching rulemaking is ensuring that the assumptions made and the techniques developed reflect reality. This assurance of reality can only be achieved through extensive and thorough testing. Field tests have been conducted in support of the Petition for Rulemaking of which this Rationale is a part. Since the technology for two-way and distributed operations can be expected to develop and improve over time and since it is desirable not to limit such developments, the testing concentrated on those aspects of systems that can be expected to remain roughly constant — namely, the interference considerations that must necessarily put limits on what can be done in two-way and distributed transmission system designs. The Field tests and their results are summarized below and are more completely described in the attached Report on Wireless Cable Two-Way Field Tests, Tucson, November, 1996 – January, 1997.

Description of Two-Way System Models

Models of two-way systems can be broken down into two principal categories: models of subscriber premises installations and models of overall system designs. Each of these, in turn, can be further broken down into several categories, each of which must be considered when devising methods and Rules for two-way operation. These models will serve as the basis for analysis of the many other facets of two-way systems.

Subscriber Installations

Subscriber installations can be set up in at least three different ways. A single Transverter can be connected to a common antenna used for both receiving and transmitting. The transverter block-downconverts received microwave signals to the VHF/UHF intermediate frequency range for reception by a set top decoder or similar device used to receive and extract both downstream data and entertainment content. The same transverter block-upconverts signals for transmission, originating in the set top decoder or an attached device, from the VHF/UHF intermediate frequency region to the appropriate microwave channels. Most likely in a transverter, the same local oscillator is used for both receiving and transmitting, so there is a fixed relationship between the VHF/UHF and the microwave spectra, determined by the choice of local oscillator frequency. The transmitter portion of a subscriber installation is termed a "response station" in the Rules with which the related Petition for Rulemaking is concerned.

The next approach to subscriber installations uses a separate transmitter and antenna for the upstream return path, while the downstream flow of data and entertainment content continue to share a single downconverter. This arrangement permits different central sites to be used for distribution and collection of the downstream and upstream data channels, respectively, although such separation is not required. It also may be useful in adding two-way capability to existing installations without requiring that previously installed rooftop equipment be taken down and reinstalled.

The third type of subscriber installation makes use of a separate receiving antenna and downconverter for downstream data channels, completely separating the data distribution function from the entertainment distribution function. This receiving functionality may be combined with the transmission hardware, using a single antenna for data applications and a separate one for entertainment, or there may actually be three antennas, one each for entertainment reception, data reception, and data transmission.

System Topologies

System topologies similarly can be described in at least three different ways. A single central site can be used for both transmission of downstream entertainment and data to subscribers and for reception of upstream data from subscribers. This is the model that historically has been used in wireless cable for distribution, with transmitting antennas positioned at as high an elevation as can be obtained and with radiated power levels as high as permitted by cost and interference considerations. Such an installation can be turned into a two-way operation by mounting receiving antenna(s) and downconverters near the transmitting antennas and sending signals in the VHF/UHF band down a cable to the receiving equipment.

The second scheme, which is already beginning to see some use for downstream distribution of entertainment, is the use of multiple transmitters of downstream signals and/or receivers of upstream signals distributed over the region to be covered. This has a number of benefits over the more conventional approach, most resulting from the fact that it reduces the distances that most signals must traverse. This reduces fading, allows a lower fade margin to be maintained, and leads to lower transmitted power levels. It also provides more uniform signal coverage. In order to minimize self-interference within the system (also called internal interference), lower antenna heights are typically used, resulting in significantly less interference caused to neighboring co-channel operations. Most important for two-way operation, distributing transmitting and receiving locations, in a manner reminiscent of cellular telephony, offers opportunities for frequency reuse (more than one simultaneous transmission per channel), thereby increasing the efficiency with which the spectrum can be utilized.

It should be noted that it is possible to combine the first two topologies, using, for instance, a central site for downstream entertainment dissemination and a number of distributed sites for two-way communications with subscriber locations. This implies the use of separate antennas at subscriber locations but offers the possibility of more easily adding two-way services on an incremental basis. In any of these arrangements, the receiving locations for upstream signals are termed "response station hubs" and may or may not be associated with downstream transmitters. Similarly, distributed downstream transmitters, other than the primary one included in the initial license for the system, are termed "boosters" whether they act to relay signals from the primary transmitter or initiate transmissions independently.

Finally, it is possible to divide the coverage areas of transmitting and receiving sites into sectors through the use of special or multiple antennas, thereby providing another means of frequency reuse. Although some characteristic, such as the frequencies used or the antenna polarization, must be alternated from sector-to-sector to permit discrimination between sectors at the sector boundaries, with a large enough number of sectors, the potential for frequency reuse increases. This technique can be combined with the use of distributed transmission and reception to achieve even higher levels of system capacity through further frequency reuse.

Wide Variety of System Situations

Because of the different licensing histories in each market and the differences in market sizes and topographies, there is a wide variety of system situations that must be taken into account in the development of two-way operating practices and distributed transmission techniques and in the promulgation of Rules. Consideration must be given to the specific licensing and leasing circumstances likely to obtain in markets and to the differing requirements for frequency reuse related to market conditions.

Specific licensing/leasing circumstances

A principal feature of wireless cable spectrum assignment under the existing FCC Rules is that channels in the 2.5-2.686 GHz band are divided into groups of four channels each, with blocks of eight adjacent channels being divided between two groups and every other channel in a block belonging to one of the pair of groups. Licensing is then generally based on assignment of complete channel groups to individual licensees. Thus assignments are made of non-adjacent channels, and adjacent channels may be licensed to or leased by different operators.

The method of channel assignment leads to non-contiguous channel plans in the 2.5-2.686 GHz region for some operators. In addition, the MDS channels at 2.15-2.162 GHz are often licensed or leased separately from the assignments in the 2.5-2.686 GHz range. Furthermore, the recent auctions of the rights to spectrum in the Basic Trading Areas (BTAs) outside the Protected Service Areas (PSAs) of incumbent licensees add many complications to the interference limitations placed on operations on certain channels within many systems, both those within PSAs and those in BTAs, where they are separately held. Thus there are many possible combinations of channels that may or may not be available to an operator and myriad possibilities for selection of channels to be used for the downstream and return paths in two-way systems. Consequently, it would be virtually impossible to prescribe *a priori* a channel plan for two-way operation by wireless cable systems that could support wide use.

Another factor that must go into the analysis of channel selections for two-way operation is the need for filtering or other techniques at the subscriber end of the path to keep the transmitted return path signal from interfering with the signals intended to be received there. If done with filtering, this separation of transmitted and received signals requires some amount of guard band between transmitted and received frequencies for the roll off regions of filter skirts. The necessary signal separation may also be provided either fully or in part by the physical separation of antennas, and this can lead to choices among certain of the subscriber installation models described previously.

Requirement for frequency reuse

The need for frequency reuse in a system depends heavily on many of the characteristics of the system. Examples are the system size, both in geography and number of subscribers, the topography of the locale in which the system is situated, and the total bandwidth needs of the system.

The more spread out a system is physically, the more it will be helped by distributing the transmission and reception points to put them closer to subscribers. This inherently helps in making frequency reuse possible, so long as a system design that supports it is put in place. Similarly, when the topography is not flat and open or when it has substantial signal blockage caused by foliage, it may benefit from distributed transmission and reception.

The most significant factors in requiring frequency reuse will be the numbers of subscribers and the total bandwidth needs of systems. Since the spectrum to support two-way operation will come at the expense of other services such as the delivery of entertainment programming, it will be used quite sparingly. Nevertheless, to be competitive, it will be necessary to deliver to large numbers of subscribers higher data rates than they can economically obtain elsewhere. Thus it will be essential to maximize the total bandwidth available, and this can only be done through spectrum reuse.

The principal techniques that will support frequency reuse are distributed transmission (cellularization) and sectorization, both of which were briefly discussed previously. Each has the ability to accommodate more users in a given part of the spectrum by dividing up the total coverage area into cells and sectors, respectively, and allowing the same part of the spectrum to be used repeatedly in many cells and sectors. The net effect is to increase the effective bandwidth of the system so that more can be made available to each individual user. There is, of course, an economic cost for the infrastructure for doing this that must be weighed against the benefits achieved. Such an economic analysis is outside the scope of this document and must be performed on a case-by-case basis in any event.

Modulation & Bandwidth Flexibility Required

In many ways, the modulation techniques and the bandwidth chosen for a system are the principal determinants of the performance of that system. Because of the wide diversity of system circumstances and the expected continuing development of the related technologies, both previously discussed, it is imperative that flexibility be accorded system operators in the selection of modulation methods, bandwidth, and other characteristics, so long as prescribed interference protection is maintained for spectrum neighbors. To grant operators the flexibility they will need, it is essential that methods be established that will ensure the interference protection required. While it is beyond the scope of this document and its associated filing with the FCC to deal with the details of modulation methods, the related aspects of bandwidth utilization and associated interference considerations are treated herein.

Establishment of standards not adequate

One way to ensure prescribed levels of interference protection is to establish standards that must be followed by all system operators. Such standardization is the way things were done in the past when developments of new techniques came along very slowly and the various services were quite homogeneous. Since the systems were open, i.e., anyone was free to obtain the necessary equipment and connect it to the system, established standards also helped assure consumers that they could purchase receivers and use them anywhere they took them. This is still the model for broadcasting today.

Wireless cable systems, on the other hand, may not be open systems; they are usually closed. Thus subscribers generally do not own the equipment they use. It is instead provided by the system operator, and its cost is built into the monthly service charge. Using closed systems, wireless cable operators can make independent choices of technologies and thereby optimize the performance and efficiency of their systems. They can update and upgrade their technology choices over time, thereby taking advantage of future developments. The value of this approach was recognized by the FCC when it recently said, "As we weigh the benefits and costs of required standards, we note that for MMDS and new services ..., we have decided to allow the marketplace to determine transmission standards.[1]"

Even if it becomes possible and worthwhile in the future to allow consumers to own the equipment they use, it is likely that the mechanism for such opening of systems will be based on the system operator providing some portion of the hardware that allows the subscriber to connect to the system and be authorized for its use. Thus there will probably be voluntary industry standards, established between the consumer electronics industry and the various delivery media, that will enable system operators to supply the interfaces to their networks in modular form and allow subscribers to plug them into their purchased equipment. Consumers will thus gain the ability to obtain and maintain the features they want while retaining for system operators control over access to their

[1] MM Docket No. 87-268, In the Matter of Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, Fifth Further Notice of Proposed Rulemaking, released May 20, 1996, at 27.

networks. Applying this model to wireless cable, mandated, regulation-based standards for modulation technology and associated channel bandwidths are unnecessary and inadequate to the industry's needs.

Many trade-offs involved in selection

As mentioned previously, the choices made with regard to modulation methods and bandwidth parameters are likely to be the principal determinants of system performance. There are many trade-offs involved in making an appropriate selection, including the data rates required to be delivered in each direction, the distances to be covered and the related values of received signal levels, carrier-to-noise (C/N) thresholds, and transmitted power levels, the frequency accuracy required to properly demodulate the signals, and the cost.

Selecting the best choice of modulation method and bandwidth parameters is a complex task of evaluating each of these characteristics, and probably others, against the system environment and against the system performance level sought. Because of all the differences in systems discussed previously, different choices are apt to be best for different systems. Nevertheless, interference to neighboring systems must be controlled at levels that permit all to coexist with relative ease. This means that even though different choices of modulation systems and parameters should be allowed, a mechanism should be established for measuring them against a common interference standard.

Channels may be subdivided & combined using Power Spectral Density

The spectrum currently allocated to wireless cable operations is assigned in channels that are 6 MHz[2] wide for downstream transmission and in response channels that are 125 kHz wide for upstream transmission. The Petition for Rulemaking of which this Rationale is a part seeks authority to use the 6 MHz channels for upstream operations as well. In addition, system optimization for two-way operation may dictate the use of channels that are narrower or wider than either 6 MHz or 125 kHz, depending upon local conditions and the state of technological development. (Of course, the use of modulation schemes wider than 6 MHz or 125 kHz will require that the operator have access to adjacent channels through licensing or leasing arrangements.)

The narrower bandwidth channels (called "subchannels" hereinafter) may be necessary as a means of controlling the number of response station transmitters present within a channel at one time or for slowing down the data rates that must be achieved by subscriber premises equipment in some applications. The wider bandwidth channels, comprising more than one 6 MHz channel ("superchannels" hereinafter), may allow

[2] Throughout the remainder of this document when 6 MHz channels are discussed, the same issues apply to the 4 MHz MDS-2A channel with the appropriate adjustments required to compensate for the narrower bandwidth.

bidirectional operation on the same channels through such techniques as buried spread spectrum.

Both subchannelization and superchannelization can easily be accommodated through use of the power spectral density (PSD) measure to relate the interference levels caused by signals in various channel widths. This approach has been previously proposed for use in the new Local Multipoint Distribution Service (LMDS), where power levels are specified exclusively in terms of power spectral density in units of dBW/MHz. While such a method could be used for MDS and ITFS calculations, given the history of licensing based on 6 MHz channels, in this discussion, power and interference levels for these services are always referred back to the power levels and desired-to-undesired signal level (D/U) ratios that pertain in 6 MHz bandwidths.

To make the power spectral density method work, it is necessary that the power spectral density of the signals be relatively uniform, as was required by the Digital Declaratory Ruling previously promulgated by the FCC. This will permit the spectrum used by neighboring operators to be subdivided into subchannels and aggregated into superchannels in different, uncoordinated ways without resulting in any differences in the interference caused one to the other. Uniform power spectral density generally requires the use of digital modulation. Since digital signals are essentially noise-like in nature, this allows their treatment in the manner of additive white Gaussian noise (AWGN), both in terms of assessing their interference potential and in terms of handling the accumulation of signal power from a multiplicity of transmitters. Interference between such uniformly distributed digital signals and analog signals can also be treated on a power spectral density basis so long as the analog signals are those previously defined for use in the full 6 MHz and 125 kHz channels, which have been studied for their interference relationships with digital signals.

Naturally, even when different bandwidths are used, D/U ratios must still be controlled in such a manner that no more interference is caused than when a standard 6 MHz channel bandwidth is transmitted. To achieve this condition, the various modulation methods, densities, and parameters are all evaluated using 6 MHz channels. A fundamental assumption is then made that the power is uniformly distributed across the channel and with time. This is the case for most digital signals but actually is not true for analog signals, which have most of their power concentrated in several carriers and in the synchronizing waveform. The power levels of analog signals are therefore determined by the envelope power coincident with the peak of sync of the video waveform rather than on the average power basis used for digital signals. Since their interference relationships with digital signals have been established using these different measurement methods,[3] the necessary D/U ratios can nonetheless be maintained.

[3] See DA 95-1854 Declaratory Ruling and Order In the Matter of Request For Declaratory Ruling on the Use of Digital Modulation by Multipoint Distribution Service and Instructional Television Fixed Service Stations at 26.

The fact that the power of the analog signals is largely concentrated at the carrier frequencies has been taken into account in establishing the allowable D/U ratios in both directions between digital and analog signals. Consequently, when calculating the power levels of both desired and undesired signals in analyzing potential interference, analog signals can be treated as though they had a uniform power spectral density with a total power in a 6 MHz bandwidth equal to the peak of sync power of the signal. This treatment will provide the appropriate level of interference protection when a digital signal with an average power level equal to the peak power level of the analog signal is substituted for the analog signal, as permitted by the Digital Declaratory Ruling.[4]

To determine the power to be used in a calculation of power flux density (PFD) at a boundary or for the desired or undesired signal in a D/U ratio, one begins by calculating first the power spectral density (PSD – in watts/Hz) allowed for the particular signal. Dividing the power level of the signal in watts by the bandwidth that it occupies gives the PSD. It is then necessary only to multiply by the bandwidth in Hz of the channel or of the other signal, depending upon the desired result, to obtain the equivalent power in the specified bandwidth. Alternatively, the ratio of the bandwidths can be calculated and converted to decibels, and the value so calculated can be added to the power of the narrower bandwidth signal or subtracted from the power of the wider bandwidth signal to obtain the equivalent power in the bandwidth of the other signal.

An example may help to clarify this situation. Suppose that interference analysis showed that a particular set of conditions would permit 100 watts of average effective isotropic radiated power (EIRP) in a 6 MHz bandwidth to be used to achieve a required level of interference protection. Suppose further that it was desired to use a 600 kHz bandwidth instead. 600,000 divided by 6,000,000 is 1/10, or -10 dB. Since a 100 watt (20 dBW) EIRP would have been allowed using 6 MHz, 10 watts (20 dBW -10 dB = 10 dBW) would be permissible for the 600 kHz application.

System Flexibility Required

Similar to the flexibility needed in the choice of channel bandwidths, flexibility in system design is also necessary for the successful deployment of two-way services. This comes from the wide variety of conditions, both business and environmental, in which systems must be constructed. There are two primary opportunities for system innovation to aid optimization of system performance. These are the use of sectorized antennas to partition the coverage area of a single site and the use of multiple transmit/receive sites to partition the service area of a system. Both forms of partitioning coverage permit frequency reuse, with its attendant spectrum efficiency, while partitioning the coverage area among several sites permits shorter transmission paths with their accompanying more uniform signal levels and higher reliability circuits.

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[4] Id at 27.

Impact of Sectorization

Sectorization requires the use of multiple antennas or a specially designed single antenna to divide the coverage from a site into a group of pie-wedge shaped zones. By establishing tiers of antennas with different elevation patterns, it is also possible to create coverage areas in annular rings surrounding the antenna site, further sectorizing coverage.

Antenna radiation patterns do not begin and end abruptly. Even in a highly directional antenna, the signal level falls off somewhat gradually outside the main signal lobe. Thus when several antennas are used to provide adjacent coverage areas, the boundaries between sectors will not be abrupt. In fact, the areas covered must partially overlap if coverage gaps are to be avoided.

Consequently, some supplementary means must be provided to help discriminate between signals emanating from adjacent sectors. This further means of discrimination can be such additional characteristics as the channels or sub-channels used for communication, the polarization of the transmitted signals, or certain features of the modulation approach used. The antenna patterns are then used to discriminate between more widely separated sectors that share the same characteristics of the means used for supplementary discrimination.

By alternating the characteristics of the signal transmissions in sequences of perhaps two, three, or four sectors, it is possible to provide sufficient signal discrimination that, by the time the sequence repeats, the antenna pattern is able to provide adequate discrimination on its own. The result is that the spectrum reuse factor is not equal to the number of sectors but is one-half, one-third, or one-quarter, respectively, of that number. Thus, if a site has 24 sectors equally spaced at 15 degree intervals and three sets of subchannels are used, the net effect will be to multiply the effective total bandwidth by 8 (24/3). It should be noted that to achieve this bandwidth increase, 24 sets of electronics – one for each sector – would be required at the hub facility.

Impact of Cellularization

The other method of partitioning the service area is the use of multiple transmit/receive sites in a scheme similar to that of cellular telephony. Many of the characteristics of this approach are similar to those just described for sectorization of coverage from a single site. Where the signal carried on a particular channel is the same in all cells, techniques are available to synchronize the transmissions so as to minimize internal interference and to maximize reliability. Where different signals are to appear in each cell, a means must be provided to discriminate between signals originating in or intended for adjacent cells, since the simple subdivision of the overall service area will not prevent internal interference.

Cellularization may be of significant benefit to operators in configuring systems for a number of reasons. It allows considerable flexibility in the placement of transmit/receive sites and in their distribution over a coverage area. Combined with the fact that lower antenna heights are needed than for single sites with wide area coverage, it can make site acquisition considerably easier. It can also provide the opportunity to reconfigure coverage over time through the addition of sites without mandating that existing subscriber antennas be re-aimed. Instead, new subscriber installations can be pointed at new sites and old subscribers can be gradually transitioned to them.

With the distribution of the transmission and/or reception functions over the service area, more uniform signal levels can be maintained, thereby increasing service reliability. The shorter distances between transmitter and receiver lead to shallower fades, lower fade margins, and therefore lower power levels. This, combined with the use of lower antenna elevations leads to smaller interference zones created around sites and permits their positioning closer to PSA/BTA or similar boundaries. When parties on both sides of such boundaries use these techniques, the service areas of both can be maximized.

Just as in the case of sectorization, methods must be provided to differentiate signals from adjacent cells since there is nothing to cause signals to abruptly fall off in level at cell edges. Particularly troublesome is the effect of successive cells appearing one behind another and "bore sighted" in the main lobe of the subscriber's antenna. In such cases, means such as those described for discriminating between signals in adjacent sectors of sectorized sites must be applied to cellularized sites. The very same methods of differentiation are available, possibly supplemented by the ability to use subscriber antenna patterns to discriminate between cell sites when they are not bore sighted. Of course, the use of signal polarization discrimination may be limited by its previous use in providing interference reduction to neighboring systems for licensing purposes.

Opportunities for combined Sectorization/Cellularization

Since many of the techniques required to support them are similar, the possibility of combining both sectorization and cellularization in a system is an attractive one. While the use of each by itself has already been demonstrated for wireless cable applications, the combination is, at this point, speculative. Nevertheless, the likelihood is that, if each can be successfully utilized, there will be some systems that will benefit from the combination. It should therefore be included among the possible techniques for two-way operation.

Interference Considerations

The FCC recently said, "Protection from interference is a fundamental Commission function that must be considered when introducing new technologies into spectrum allocations currently in use.[5]" Since the Commission has also said that it will leave

[5] MM Docket No. 87-268, In the Matter of Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service, Fifth Further Notice of Proposed Rulemaking, released May 20, 1996, at 46.

MMDS transmission standards to the marketplace, providing appropriate levels of interference protection is expected to be the principal focus of the Commission's interests in authorizing two-way operation for wireless cable, as well it should be. From the standpoint of Rules to support two-way operation of wireless cable systems, interference considerations are the crux of the matter.

Interference issues can be broken down in many ways, all of them based upon the relationship between a station or operation causing interference and the station or operation receiving the interference. Each of the possible combinations of such relationships must be explored, with the objective of providing mechanisms for interference protection in all cases. In studying interference issues with respect to two-way wireless cable operations, certain categories are useful in dividing the problem into manageable parts. To be investigated in this discussion are co-channel interference, and adjacent channel interference.

The model assumed in examining the many possibilities for interference is one that may include multiple transmitters sending signals from the system to subscribers – i.e., downstream – including both distributed and sectorized transmission sites, and that may include a large number of transmitters sending signals from subscribers to the system – i.e., upstream – potentially aimed at a number of distributed receiving hubs. All of these transmitters must be considered in conjunction with the categories of interference when determining methods for achieving acceptable levels of interference protection.

Co-Channel interference

Co-channel interference occurs when two transmitters are operating in the same channel. Because the receiver is essentially tuned to both the desired and the undesired signals simultaneously, there is little that can be done in the receiver design to protect against co-channel interference. The only form that co-channel protection can take is to separate by an appropriate amount the levels of the two signals, through either physical separation of the transmitters, antenna directivity, signal polarization diversity, choice of modulation techniques, or through a combination of these methods.

Co-channel interference is principally of concern with respect to interference caused to neighboring systems, be they PSA- or BTA-bounded. In two-way systems, co-channel interference can originate from either downstream or upstream transmitters. The cumulative effects of signals emanating from multiple sources must be determined when predicting interference to contiguous operations.

Co-channel interference will also exist internally within systems when multiple transmitters are used on the same channel in whichever stream direction. This is an engineering consideration that mostly has to do with system performance and capacity. It may be possible to mitigate its effect with improved system designs, and operators may implement advanced techniques, over time, as they become available to reduce its impact. It is not, however, an issue that would benefit from inclusion in any form in the FCC Rules.

It should be noted that, in the Petition of which this Rationale is a part, the existing interference limit applicable to co-channel signals, i.e., a 45 dB desired-to-undesired signal (D/U) ratio, is assumed to continue in effect. Just as noted in the Petition for Declaratory Ruling and its supporting documentation, it remains adequate for the interim to assure that interference will not be increased by the additional forms of transmission proposed herein. Additional testing is required to derive possible new values for the signal ratios that control interference, and any changes to be made will be requested in a separate Petition. No changes to the -73 dBW/m^2 power flux density at boundaries between PSAs and BTAs are comtemplated.

Adjacent channel interference

Adjacent channel interference takes two forms. First is the signal in the adjacent channel that sneaks past the selectivity of the receiver to the receiver's detector. This results from receiver imperfections that are the inevitable consequence of building receivers economically. Second is the signal that is transmitted in the desired channel by a transmitter operating in the adjacent channel – in essence, "adjacent channel co-channel" interference. This results from the spreading of the signal spectrum in the transmitter due to transmitter non-linearities that cause intermodulation distortion products.

Closely associated with the second form of adjacent channel interference is the "spectral mask" of the transmitter that defines the acceptable level of adjacent channel co-channel interference. The spectral mask specifies the reduction in energy required in the output of a transmitter at certain points in the spectrum outside the channel of operation. In order to specify properly the acceptable level of adjacent channel signal, it is necessary also to specify the spectral mask of the interfering transmitter.

The relative significance of the two forms of adjacent channel interference is determined largely by receiver design. A receiver with good adjacent channel selectivity will ignore the signal in the adjacent channel and respond mostly to the second form of interference. A receiver with poor adjacent channel selectivity will respond strongly to the signal in the adjacent channel, the presence of which will overwhelm the effects of the adjacent channel transmitter's co-channel output.

Adjacent channel interference is principally of concern with respect to interference caused to intermingled systems, i.e., systems in which adjacent channels are used by different operations. In two-way systems, adjacent channel interference can originate from downstream transmitters or from upstream transmitters. The cumulative effects of signals emanating from multiple sources must be determined when predicting interference to intermingled operations. The potential impacts of transmitters operating in close proximity to adjacent channel receivers must also be taken into account in situations with intermingled systems.

Adjacent channel interference will also exist internally within systems when transmitters are used on adjacent channels in either direction. This is once again an engineering consideration that mostly has to do with system performance and capacity. It may be possible to mitigate its effect with improved system designs, and operators may implement advanced techniques, over time, as they become available to reduce its impact. It is not, however, an issue that would benefit from inclusion in any form in the FCC Rules.

Of similar concern to that regarding adjacent channel interference will be out-of-band emissions. Even where adjacent channels within the band are used by a single operator and adjacent channel interference may thus be treated as an internal system engineering matter, consideration must be given to operations of other services in spectrum allocations adjacent to those used by wireless cable. This will be significant for operations on channels MDS 1, MDS 2, A1, and G4, and the response channels allocated within the spectrum space of erstwhile channel H4.

It should be noted again that, in the Petition of which this Rationale is a part, the existing interference limit applicable to adjacent channel signals, i.e., a 0 dB desired-to-undesired signal (D/U) ratio, is assumed to continue in effect. Just as noted in the Petition for Declaratory Ruling and its supporting documentation, it remains adequate for the interim to assure that interference will not be increased by the additional forms of transmission proposed herein. Additional testing is required to derive possible new values for the signal ratios that control interference, and any changes to be made will be requested in a separate Petition.

Spectral Mask

To control the amount of "adjacent channel co-channel" interference a station is permitted to transmit. a spectral mask is used to limit the amount of out-of-channel power at various locations in the spectrum surrounding the channel of operation. A spectral mask typically specifies, relative to the licensed or operating power of the transmitter, the amount of power allowed at the channel edges, at some defined spectrum locations away from the channel edges, and at all other locations in the spectrum.

6 MHz Channels

Testing done in support of the Petition for Declaratory Ruling established that adequate interference performance could be achieved in the 6 MHz channels with a spectral mask having power at the channel edges 35 dB below average power in the channel and power 3 MHz or more away from the nearest channel edge 57 dB below average power in the channel.[6] Nevertheless, the spectral mask proposed on an interim basis and adopted by the Commission in the Digital Declaratory Ruling specified power at the channel edges

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[6] See "Report on Wireless Cable Interference Testing, April 27-May 4, 1995," attachment to "Rationale for Interim Implementation of Wireless Cable Digital Transmission," Appendix B to the Petition for Declaratory Ruling, at pages 9, 23, and 34, and Charts 7, 8, 13, 14, 17, 18, and 19. (The "Digital Testing Report.")

38 dB or more below average power in the channel and power 3 MHz or more away from the nearest channel edge 60 dB or more below average power in the channel. This proposal was made and adopted in the spirit of being very conservative in providing interference protection to adjacent channel stations, just as the selection of CCIR Grade 4 for the threshold in interference measurements made in support of the Digital Declaratory Ruling was much more conservative than the equivalent of CCIR Grade 3 upon which all of the wireless cable Rules up to that time were based. It also made use of the numbers already existing in the analog Rules with as little modification as possible in order to facilitate a declaratory ruling.

For the purpose of moving forward with the beginning of the permanent Rules for digital wireless cable operations, as embodied in this filing, it is timely to incorporate a digital spectral mask into the Rules so as to permit type acceptance on an appropriate basis. (It is also important to establish a spectral mask for the 125 kHz channels that allows for more efficient use of that spectrum, as will be discussed momentarily.) At the same time, it should be noted that the earlier testing did demonstrate a substantial margin even with a relaxed spectral mask. With the two adjacent channels each having -35 dB at their channel edges and -57 dB at the middle of the desired channel ("Mask 2"), the resulting signal level was -54 dB at the middle of the desired channel. CCIR grade 4 performance was achieved with a minimum of -4 dB D/U ratio under these circumstances. The fact that the threshold D/U ratio increased by less than 1 dB even though the interfering adjacent channel out-of-channel signals increased by 3 dB indicates that the "adjacent channel co-channel" noise (i.e., the spectral mask) was not the primary factor in determining adjacent channel interference; rather the strength of those adjacent channel signals within the passband of the receivers was.

Given the described conditions, it can be concluded that, at a minimum, the adjacent channels could be operated at 0 dB D/U with -50 dB total out-of-band power in the middle of the desired channel while still achieving CCIR grade 4 performance. Since the spectral mask is not the controlling factor, it is reasonable to infer that an even lower D/U ratio (i.e., having negative values) could be used while achieving CCIR grade 3 performance. Thus it is quite sensible to relax the spectral mask now used under the provisions of the Declaratory Ruling on an interim basis. Inasmuch as the measurements discussed were all made using analog signals for the desired channels, any changes should be made carefully until full testing with digital signals is completed.

Consequently, even though the spectral mask could be relaxed for all transmitters, as just demonstrated, it is proposed to maintain for all high-power emitters, including both transmitters and single-channel boosters, the spectral mask for 6 MHz channels provided in the Petition for Declaratory Ruling, i.e., 38 dB or more below the licensed average power at the channel edges and 60 dB or more below licensed power at points 3 MHz removed from the nearest channel edge and beyond. This is appropriate because of the relatively high power per channel that can be produced by such devices and the relatively large geographic areas over which they can produce interference. It is also the case that industry designs are completed to the tighter standard, that it has been adopted in practice, and that it is not unreasonably expensive to implement. It may, however, be appropriate to relax the spectral mask these devices at some time in the future in order to further reduce the cost and complexity of transmitters and single channel boosters.

Where broadband boosters are concerned, however, a different approach is required. Broadband boosters are devices that amplify a wide frequency range, i.e., a large number of channels, through a single amplifier. Their use is driven primarily by the need to achieve coverage improvement at very low cost. Since they can cover only very small or modest areas, depending upon whether they are registered (<-9 dBW EIRP) or licensed (>-9 dBW EIRP) devices, respectively, only a small amount can be invested in them if they are to be of real use. It is that same limitation in coverage that makes it reasonable to relax the spectral mask for broadband boosters, since they will not be able to create interference over a very wide area.

The proposal is to relax the spectral mask requirements for high power broadband boosters (those exceeding -9 dBW EIRP) to require 38 dB or more attenuation at the edges of channels adjacent to unoccupied channels and 50 dB or more attenuation at points within the 2.500-2.686 GHz band at and beyond 3 MHz from the nearest edge of any occupied channels. For points outside the 2.500-2.686 GHz band, attenuation of 50 dB or more would be required at 3 MHz from the nearest band edges, increasing linearly to 60 dB or more attenuation at points 20 MHz from the nearest band edges and beyond. For broadband boosters operating in the MDS channels, required attenuation would be 38 dB or more at the edges of the 2.150-2.160/2 GHz band and 60 dB or more at points 3 MHz from the nearest band edges and beyond.

For low power broadband boosters (those below -9 dBW EIRP — 1/8 Watt total radiated across all channels carried by the booster), it is proposed to have no spectral mask requirement. This results from the facts that the economics are even more significant, that the area that can be impacted is very much smaller, and that any actual interference that results can trigger a requirement from the FCC of better performance. Interference caused by such devices will tend to be self-limiting, in any event, since any noise that is radiated in unoccupied channels also will be radiated in the occupied channels, thereby interfering with the very signals the booster is intended to carry. (This can also be said of "high power" boosters.)

125 kHz Channels

Similar to that for 6 MHz channels, a spectral mask specification is needed for the 125 kHz response channels. Currently, the ITFS Rules (at §74.939(f)) specify that any emissions outside the channel must be attenuated at least 60 dB. The MDS Rules do not specify any such channel occupancy limitations. To make efficient use of the 125 kHz channels, some out-of-channel power should be permitted so that a large proportion of the channel does not have to be reserved for guard bands when digital signals are used. At the same time, a condition of no limitation, as in the MDS Rules, goes too far.

Proposed at this time is a spectral mask having a structure similar to that proposed in the Petition for Declaratory Ruling. The values are changed somewhat in recognition of the findings of the testing done earlier and the need to minimize the economic impact on devices intended for installations in consumer quantities. The proposal is intended to be a balance between conflicting goals that provides good spectrum efficiency at a reasonable cost.

Thus the spectral mask included in the proposed changes to the Rules for 125 kHz channels provides for signals to be attenuated by 35 dB at the channel edges and by 60 dB 125 kHz above and below the nearest channel edges and beyond. Since the channels involved are relatively narrow, there is no possibility to put channel-width filters on the outputs of transmitters at the frequencies involved. Thus a moderate amount of room must be provided for the fall-off of the intermodulation skirts of digital signals. The bandwidth of one channel has been allowed for this purpose.

Response stations

The spectral masks described in the two immediately preceeding subsections are intended to define the overall performance that will be required of transmitters in the 6 MHz and 125 kHz channels. For high power transmitters, of which there will be relatively few, that is all that is required. When response stations are involved, it is recognized that there are certain difficulties in meeting the total requirements of the described spectral masks because of the complications of reducing discrete spurious products to the specified levels in equipment designed for consumer applications and cost structures. For these reasons, an exception is provided for response station transmitters allowing the existence of discrete spurious signals in the outputs of the transmitters that are reduced by at least 40 dB from the power in the channel, that occur no more frequently than once every 10 MHz, and that do not occur more than 50 MHz from the frequency of operation.

The exception is justified from an interference point of view by the facts that the response station transmitter outputs will be relatively low in power, that directional transmitting antennas will be used thereby reducing the area of potential interference from any individual transmitter, and that the duty cycle of operation of individual response stations will generally be low, all of which reduce both the zones and the periods of potential interference from individual response stations. Emphasis is placed on the conditions surrounding individual response stations because, with the low powers involved, only receivers in close proximity to individual transmitters have the potential to receive any interference from the spurious emissions.

Frequency Tolerance

The frequency tolerance applied to transmitters can serve several purposes. Primarily, it maintains the location of the signal in the channel so that interference relationships to both cochannel and adjacent channel neighbors meet expectations. It can help reduce visible interference when precise frequency control is established with respect to analog signals, both with other analog signals and with certain types of digital signals. It can also allow maximum utilization of the spectrum when relatively narrow channels are spaced closely together. Beyond the frequency tolerance requirements that appear in the FCC Rules, system designs may benefit from even tighter tolerances by allowing more advanced modulation methods or much closer spacing of subchannels than would be possible otherwise. In the associated Petition, different frequency tolerances are proposed to be applied to transmitters in each of two categories based on the power levels involved.

High power transmitters

High power transmitters are all primary transmitters plus booster transmitters with power exceeding -9 dBW EIRP. They often have wide coverage areas and the opportunity to cause significant interference to neighboring cochannel systems. They also can have a substantial impact on adjacent channel signals. Under these circumstances, it is appropriate to mandate that a reasonably tight frequency tolerance be maintained. Thus it is proposed that these transmitters be required to meet a ±1 kHz (approximately ±0.00004 per cent) accuracy requirement.

Low power transmitters

Low power transmitters include boosters with power up to -9 dBW EIRP and all response stations. These transmitters have relatively localized coverage areas and thus little opportunity to cause widespread interference. They generally will have little impact on adjacent channel signals. In this situation, there is little need for tight frequency control for interference reasons. Thus it is proposed that these transmitters not be mandated to meet any particular frequency tolerance but rather be required to stay within the limitations of the specific spectral mask applicable to them.

Sub-Channelization

The term sub-channelization, as used here, refers to the subdivision of channels established for licensing purposes into smaller channels used for actual communications. This may be desirable, especially for response station transmissions, to allow a moderate number of transmitters to be operated simultaneously without interfering with one another. Sub-channelization of this sort supports frequency division multiplexing and may be needed to allow the alternation of channel utilization from one channel to another in adjacent sectors or cells in systems having subdivided service areas. Sub-channelization can also be used to optimize the data rates of transmitters so that the spectrum is used efficiently, without requiring that consumer grade equipment have the capacity to operate at the speeds needed to fully fill wide channels.

6 MHz channels

The 6 MHz channels can be subdivided in many ways. Very often the best plan will turn on the type of modulation to be used. For example, code division multiple access

(CDMA) methods at low data rates may suggest the use of four or five subchannels with bandwidths on the order of 1¼-1½ MHz, relatively low transmitter power, and a high frequency reuse ratio. Meanwhile, higher bit rates can be transmitted by more conventional modulation forms such as quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM), perhaps also using time division multiplexing (TDM) methods, but at the expense of requiring more transmitted power and supporting fewer simulaneous transmissions in a given portion of the spectrum. This type of frequency division multiplexing (FDM) can result in up to a hundred or more subchannels in a 6 MHz channel.

When a 6 MHz channel is subdivided, it is important to ensure that the out-of-channel emissions will be no greater than provided in the spectral mask for single transmitters in 6 MHz channels. Because the transmitters that will be used for response stations must be low in cost as a result of the volume that will be required, it may not be possible to apply filtering to the same extent as in high power downstream transmitters for control of such emissions. Thus it may be necessary to include in channel plans some amount of guard band at the edges of the 6 MHz channels to allow for the fall-off of the out-of-channel power to the level required at the 6 MHz channel edges. This will be discussed further below in the section on response stations and hubs.

125 kHz channels

The 125 kHz response channels offer less opportunity for sub-channelization, yet the possibility for benefit from such an approach exists. The number of such subchannels might range from two to ten and would be limited by the need for much tighter frequency control with smaller width channels. Again, the type of modulation employed will have a large impact on the subdivision of the licensed channel into smaller subchannels.

When a 125 kHz channel is subdivided, it is important to ensure that the out-of-channel emissions will be no greater than provided in the spectral mask for single transmitters in full 125 kHz channels. Because the transmitters that will be used for response stations must be low in cost as a result of the volume that will be required, it may not be possible to apply filtering to the same extent as in high power downstream transmitters for control of such emissions. Thus it may be necessary to include in channel plans some amount of guard band at the edges of the 125 kHz channels to allow for the fall-off of the out-of-channel power to the level required at the 125 kHz channel edges. This will be discussed further below in the section on response stations and hubs.

Power spectal density limitations

The sub-channelization of the licensed channels leads to different interference relationships between the signals in the subchannels than those contemplated by the fundamental limits currently imposed by the FCC Rules, namely 45 dB co-channel and 0 dB adjacent channel. This can easily be accommodated through use of the power spectral density to relate the various widths of channels, as discussed above. To avoid the need to directly relate the power in the subchannels of one system to subchannels potentially of a different bandwidth in a neighboring system, it is convenient always to relate the powers involved to a 6 MHz bandwidth.

It is important to note that previously there have been no interference limitations applied to the 125 kHz response channels. As described in the proposed changes to the Rules that are a part of this filing, it is intended in the future to apply the same interference criteria to the 125 kHz channels as are applied to the 6 MHz channels, currently the 45 dB and 0 dB values. These will be calculated at the response station hub for the 125 kHz channels using the minimum received signal levels that are required to be filed as part of the application procedure for response station hubs. When power levels must be determined, as in the -73 dBW/m^2 limitation at PSA and BTA boundaries, the power spectral density of a 6 MHz channel is used. The result is that the power in a 125 kHz channel must be reduced at a boundary to -89.8 dBW/m^2 when the differences in bandwidths are taken into account. (125 kHz/6 MHz = 1/48 = -16.8 dB)

Super-Channelization

Just as it is possible to subdivide channels into narrower subchannels, it is also possible to combine them to create wider channels, hereinafter called superchannels. This may be necessary when it is required to transmit moderate to high data rates at relatively low power, which can be accomplished using spread spectrum techniques. Indeed, with sufficient bandwidth used for the transmissions, it is theoretically possible to utilize the same spectrum for transmissions in both directions with a technique called "buried spread spectrum." Proposals for practical systems that take advantage of buried spread spectrum have been made and are currently under investigation. There may also be other technical possibilities for use of wider than normal channels. Consequently, the proposed changes in the Rules, which are intended to allow the maximum amount of flexibility in designing systems for both downstream and upstream transmissions, provide the ability to create wider superchannels in addition to narrower subchannels.

6 MHz channels

In order to combine adjacent 6 MHz channels into wider bandwidth superchannels, it will be necessary for the operator to have licensed or leased access to all of the channels to be combined and for the channels to have nearly identical facilities authorized. When 6 MHz channels are combined, the out-of-band emissions limitations applicable to 6 MHz channels apply, but only at the outer edges of the superchannel and not at the common channel edge(s) of the combined channels. In this case, the out-of-band emissions at each end of the superchannel are measured with respect to the power that is permitted in each of the individual 6 MHz channels and not with respect to the combined power of the overall superchannel. In this way, the radiated out-of-band emissions are no greater than they would have been if the channels had not been combined and the interference protection offered to adjacent channel stations remains unchanged.

125 kHz channels

The combination of adjacent 125 kHz channels into wider bandwidth superchannels will require that the operator have licensed or leased access to all of the channels to be combined through similar access to the underlying 6 MHz channels and that the channels have nearly identical facilities authorized. When 125 kHz channels are combined, the out-of-band emissions limitations applicable to 125 kHz channels apply, but only at the outer edges of the superchannel and not at the common channel edge(s) of the combined channels. In this case, the out-of-band emissions at each end of the superchannel are measured with respect to the power that is permitted in each of the individual 125 kHz channels and not with respect to the combined power of the overall superchannel. In this way, the radiated out-of-band emissions are no greater than they would have been if the channels had not been combined and the interference protection offered to adjacent channel stations remains unchanged.

Power spectral density limitations

When superchannels are used, whether based on combinations of 6 MHz or 125 kHz channels, the power that may be radiated in any one of the channels constituting the superchannel must be limited to the power that would have been radiated in that channel if it were used independently. In other words, the total power in the superchannel may equal the sum of the powers that are permissible in the individual channels, and the power must be uniformly distributed over the superchannel just as it would be over a single channel. In this way, the radiated emissions within any of the constituent channels are no greater than they would have been if the channels had not been combined and the interference protection offered to co-channel stations remains unchanged.

Distributed Transmission

The benefits of distributing downstream transmitters and/or upstream receivers in a network throughout a service area have already been discussed. There are a number of other considerations that come into play, however, when designing a system intended to reap those benefits. The principal purpose of the network will determine which of two primary topologies will be used in the network. In one, the signals emanating from all the transmitters are the same, and the purpose is to provide more uniform signal levels and to generally improve reception at all locations throughout the service area. In the other, the signals transmitted at each location are different, and the purpose is frequency reuse, effectively multiplying the capacity of the system. It is, of course, possible to have both network configurations within a system, on different channels but sharing common transmission facilities.

When the purpose is downstream transmission, there are two fundamental network designs. In the first, a single transmitter will originate the signal, and booster transmitters will relay the signal after picking it up over the air. This has been the classic use of "boosters" in wireless cable. It is the least difficult and expensive to implement but limits the designer's ability to control interference between transmitters in the system ("internal" or "self-" interference). In the second design, the transmitters are fed a signal, either at baseband or already modulated, over a separate path from that used to transmit to subscribers. This allows the timing of the transmissions from the various transmitters to be adjusted with respect to one another so as to minimize internal interference in the system. When this approach is used with digital signals, the adaptive equalizer that is used in a digital receiver can treat interfering signals received from transmitters within the system, other than the one at which the antenna for that location is aimed, as echoes, effectively cancelling them. This method is considerably more difficult and expensive to implement but has the potential to reach a larger portion of the potential audience. It is one of the reasons that the proposed changes to the Rules include the ability of booster stations to originate signals.

When the purpose is frequency reuse, the signal from each of the multiplicity of transmitters is different from the others. This eliminates any possibility of treating interfering signals as echoes; interference reduction must come through more conventional methods such as antenna directivity, cross polarization of antennas, channel diversity, and terrain shielding. Signals must be delivered to and from the transmitter and receiver using a separate path from the connection to subscribers. It is the other and really the main reason that the proposed Rules changes include origination of signals by what the Rules call "boosters."

Interference from multiple transmitters

In all of the cases just described, the interference impact on neighboring co-channel or adjacent channel stations will be essentially the same, no matter how the transmitters are networked. The power from the multiplicity of transmitters will accumulate or aggregate by the direct addition of the power from each reaching a particular receiving location. Thus interference studies can be conducted without regard to the network design.

The current Rules provide only that the interference from a transmitter or from a booster, taken separately, must meet the required criteria (currently 45 dB co-channel and 0 dB adjacent channel). This does not really offer the protection intended for neighboring stations since each transmitter individually may meet a particular interference criterion, but the combined power from several such transmitters can easily be 3-6 dB worse. For these reasons, the proposed changes in the Rules require that the total power from the primary transmitter and all booster transmitters in a system impinging on a neighboring system be used in interference calculations.

Since interference calculations are generally done in decibels, when accumulating the power from a multiplicity of transmitters, it is necessary to convert the power as expressed in dB to Watts, perform the addition, then convert the result back to dB. The value obtained in this way can then be used in the ordinary determination of interference ratios by usual methods.

Response Stations & Hubs

Response stations and response station hubs are the means by which two-way operation of wireless cable systems will be enabled. Response stations embody the transmission function from subscriber premises locations, whether actually implemented as separate transmitters or as parts of transverters and whether separate antennas are used for return path transmission or combined transmitting/receiving antennas are installed. Response station hubs serve as the collection points for signals from the response stations in a multi-point-to-point configuration for upstream signal flow, just the opposite of the point-to-multi-point signal flow in the downstream direction.

Because of the potentially very large number of response stations, the computation of potential interference they may cause promises to be among the most complex of calculations needed in planning wireless cable systems. A procedure for carrying out the necessary studies is described below and included in the Petition for Rulemaking of which this Rationale is a part. Similarly, because of the likely elevated locations of response station hubs, interference into their receivers is likely to be a principal determinant of the performance of response systems.

Protected receiving sites

Unlike the conventional receiving situation in wireless cable installations, the receiving antenna at a response station hub most often will have an omnidirectional pattern or an array of directional patterns that, taken together, are essentially omnidirectional. Also unlike the normal situation, the receiving antenna at a response station hub will be fairly high so as to be visible to the largest proportion of locations where response stations may be sited. Given these circumstances, it is probable that response station hubs will have line-of-sight to co-channel downstream transmitters where neighboring systems use the same channel in the opposite direction as one using it for upstream transmissions. This is likely to make it difficult to engineer response systems without coordination between neighbors and suggests the use of the same channel(s) for upstream operations by all systems in a moderately wide region.

In any event, once a system has been designed and authorized, with whatever amount of interference it may experience initially, the system must be protected from any additional interference from new stations that neighbors may seek to install. This protection is accomplished by offering the response station hub the same protection a receiver would obtain if that receiver were intended for downstream reception purposes. Thus, under the current interference criteria, it will be protected to a minimum of 45 dB D/U co-channel and 0 dB D/U on adjacent channels and/or to a signal level of -73 dBW/m^2 in a 6 MHz channel at the geographic boundary, depending upon whether it is installed in an incumbent PSA or a BTA, respectively.

In order to predict the interference ratios at a response station hub, it is necessary to know the received signal level of the desired signals so that the ratio with respect to the undesired signals can be calculated. As will be explained shortly, the signal levels from all response stations are not likely to be identical. Consequently, it is necessary to specify a signal level value to be protected. This is taken to be the lowest signal level, expressed in $dBW/m^2/Hz$, at which the combination of receiving antenna and receiver can properly lock-on to and decode signals from the response stations. The use of the $dBW/m^2/Hz$ measure, a combination of power flux density and power spectral density, makes the threshold value independent of the particular channel plan in use at any given time and allows the operator of the response station hub to change channel plans without affecting the interference protection burden placed on neighboring systems.

While it is likely that most of the signals arriving at the response station hub will be somewhat higher in level than the minimum level, its use serves to protect the weakest signals from response stations that the response station hub would be able to receive absent interference. Of course, this level of protection will only have to be afforded by proposed new facilities, not those in existence prior to the date of application for authorization of the response station hub. Furthermore, the validity of the level specified in an application will be relatively easy to verify, given the other information required to be supplied in the application for a response station hub.

Transmitter operating conditions

Many factors will impact the ultimate communications reliability of any particular response station installation. Among these factors will be choices made at the system level and the characteristics of the specific installation. One design goal at the system level is apt to be having all of the signals from the many response stations arrive at the response station hub at roughly the same signal level. This goal will be important because it will minimize the amount of level slewing that the receiver will undergo when switching from receiving signals from one response station to those from another. This, in turn, will minimize the delay caused by the automatic gain control time constant and thereby minimize any guard interval that might be required between receiving transmissions from one station and those from another. The end result will be to maximize the efficiency of the system.

Obtaining essentially equal signal levels from all response stations may be as simple a function as choosing the right gains in the transmitting antennas and/or installing appropriate attenuators at the time of installation, or it may be as complex as incorporating closed loop control over the transmitter powers by measuring signal levels at the receiver and feeding back control information to the response stations.[7] Whichever route is chosen, it is likely that not all signals will arrive at the desired level. This will

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[7] It should be noted that no limit for response station EIRP is specified in the proposed changes to the Rules. This is to allow system designers maximum flexibility and to provide maximum opportunity to operators to render service over difficult transmission paths. The power levels that can be used in practice will be inherently limited by the requirements for interference protection.